EFFECT OF MILITARY TRAINING ON INDICATORS OF SOIL QUALITY AT FORT BENNING, GEORGIA

Charles T. Garten, Jr., Tom L. Ashwood, and Virginia H. Dale

Environmental Sciences Division, Oak Ridge National laboratory

ABSTRACT

The purpose of this research was to investigate the effects of soil disturbance on several key indicators of soil quality at Fort Benning, Georgia. Military activities at Fort Benning that result in soil disturbance include infantry, artillery, wheeled, and tracked vehicle training. Soil samples were collected along a disturbance gradient that included: (1) reference sites, (2) light military use, (3) moderate military use, (4) heavy military use, and (5) remediated sites. With the exception of surface soil bulk density, measured soil properties at reference and light military use sites were similar. Relative to reference sites, greater surface soil bulk density, lower soil C concentrations, and less C and N in particulate organic matter (POM) were found at moderate use, heavy use, and remediated sites. Studies along a pine forest chronosequence indicated that POM-C stocks gradually increased with stand age. An analysis of soil C/N ratios, as well as soil C concentrations and stocks, indicated a recovery of soil quality at moderate military use and remediated sites relative to heavy military use sites. Measurements of soil C and N are ecological indicators that can be used by military land managers to identify incipient changes in soil quality and to rank training areas on the basis of soil quality.

INTRODUCTION

Military land managers are faced with the challenge of using a given amount of land for the purpose of military training and troop readiness. The mission must be accomplished in a manner that meets military requirements and also promotes the sustainability of ecosystems so that the military mission is not compromised by a degraded landscape.

Military installations are representative of a larger set of issues faced by managers of many government lands. Areas set aside for the public's benefit, like national parks and recreational areas, can suffer a slow and almost undetectable degradation if the land is over-utilized by long-term human activities.

Sustainability of terrestrial ecosystems depends, in part, on soil quality. Soil organic matter (soil C) and soil nitrogen (N) are critical determinants of soil quality because of their relationship to soil structure and nutrient supply. Soil organic matter plays an essential part in soil aggregate formation, soil structure, and infiltration capacity. Free organic matter, consisting mainly of fresh plant residues, is an important energy source for heterotrophic soil microorganisms and plant available soil N. Total soil C and N are potential ecological indicators that could help land managers determine when there is some incipient change in the landscape that could signal either a disturbance or a recovery of soil quality.

Disturbance of soil physical properties and/or soil structure is a commonly reported effect associated with the use of heavy vehicles in military training, forestry, and agriculture. The purpose of this study was to investigate the effect of soil disturbance on measures of soil C and N at Fort Benning.

CHARACTERIZATION OF DISTURBANCE CATEGORIES

Study sites were classified into different disturbance categories:

Reference Sites -- defined as pine forests with only minimal infantry training, including a 28-year old mixed pine stand, a 68-year old longleaf pine stand, and a 74-year old longleaf pine stand.

Light Military Use Sites -- included 3 sites used only for infantry training: a 65-year old longleaf pine stand, a 77-year old longleaf pine stand, and a 109-year old mixed pine stand.

Moderate Military Use Sites -- were selected adjacent to 3 sites that had been used for tracked vehicle training, with no forest overstory and about 25 to 50% bare ground.

Heavy Military Use Sites -- included 3 sites recently used for tracked vehicle training, with no overstory vegetation and ≥95% bare ground.

Remediated Sites -- 2 recently planted longleaf pine plantations on highly disturbed soils: one stand was 2-5 years old and the second was 8-10 years old, with 0-50% bare ground.

METHODS

Soil Sampling

Surface mineral soil samples were collected in September and October, 1999 to a mean depth of 22 cm along a transect at each study site. Each sampling transect was 60 m long, and soil samples were taken at 5 equally spaced points along the transect.

Soil Sample Preparation

Soil samples were air dried to a constant weight at room temperature (21 ±1 °C). Dry soil samples were crushed and passed through a 2 mm sieve to remove gravel and coarse organic debris. A subsample of soil (< 2 mm) from each jar was ground and homogenized using a mortar and pestle prior to elemental analysis.

Analysis of Particulate Organic Matter

Organic matter in the surface soil samples was separated into particulate organic matter (POM) and mineral-associated organic matter (MOM) by wet sieving methods (Cambardella and Elliott, 1992). Both fractions were weighed after oven drying (65 °C) and ground using a mortar and pestle.

Analysis of Refractory Soil Carbon

Controlled ground fires are a common management practice used at Fort Benning. These fires can produce charcoal, a highly refractory form of soil C. Charcoal in each POM fraction was evaluated using acid-base digestions in an attempt to correct calculated POM-C stocks, which are highly labile, for the presence of refractory soil C. Two grams of POM was digested in 20 mL of boiling 1 N hydrochloric acid (HCl), followed by boiling 2 M sodium hydroxide and boiling 6 N HCl (each one hour). The final residue was recovered by filtration, thoroughly washed with distilled water and oven dried prior to elemental analysis. A sand-charcoal "standard" was made by mixing activated charcoal with dry, ignited beach sand. Replicate samples of the standard (0.82 %C) were analyzed for refractory C using the same methods as applied to the POM fractions.

Elemental Analysis

Whole soils and different soil fractions were analyzed for total C and N concentrations using a Perkin-Elmer 2400 Series II CHNS/O Analyzer (Perkin-Elmer Analytical Instruments, Norwalk, CT).

RESULTS

Table 1. Mean (and CV) surface soil bulk density, C concentrations, C stocks, N stocks, and C/N ratios at Fort Benning, GA. Means in the same row with different letters are significantly different. N = 15, except RM (=10).

Variable	Disturbance Category* RF	LU	HU	MU	RM
Soil bulk density (g cm-3)	1.25a (0.09)	1.38b (0.10)	1.53c (0.08)	1.51c (0.06)	1.51c (0.06)
C concentration (%)	0.92a (0.35)	0.98a (0.50)	0.17b (0.44)	0.56c (0.46)	0.55c (0.33)
C stock (mg C cm-2)	226a (0.30)	260a (0.42)	53b (0.46)	167c (0.42)	164c (0.30)
N stock (mg N cm-2)	6.11ab (0.24)	7.70a (0.38)	5.03b (0.39)	7.93a (0.41)	6.24ab (0.68)
Soil C/N ratio	38.8a (0.38)	34.0a (0.18)	12.8b (0.68)	21.8c (0.33)	31.7a (0.39)

Table 2. Mean (and CV) C and N in particulate organic matter (POM), mineral associated organic matter (MOM), refractory soil C , and corrected POM-C stocks (adjusted for amounts of refractory soil C) in surface soils at Fort Benning, GA. Means in the same row with different letters are significantly different. N = 3, except RM (=2).

Variable (Units)	Disturbance category* RF	LU	HU	MU	RM
Uncorrected POM-C (mg POM-C g-1 soil)	4.25a (0.34)	4.11a (0.24)	0.35b (0.54)	1.15b (0.44)	1.51b (0.21)
Refractory C (Fraction)	0.36a (0.19)	0.37a (0.21)	0.67a (0.57)	0.37a (0.60)	0.33a (0.14)
Corrected POM-C (mg POM-C g-1 soil)	2.67a (0.24)	2.62a (0.28)	0.16b (1.21)	0.76b (0.63)	1.02b (0.28)
MOM-C (mg MOM-C g-1 soil)	5.35a (0.27)	5.70a (0.39)	1.42b (0.32)	4.96a (0.02)	3.34ab (0.10)
Refractory C (mg C g-1 soil)	1.58a (0.53)	1.49a (0.32)	0.19b (0.48)	0.39b (0.40)	0.49b (0.07)

* RF = reference site; LU = light military use, HU = heavy military use, MU = moderate miliatry use, RM = remediated site

DISCUSSION

Reference and light use sites were similar with respect to all measured properties, except for soil bulk density. Higher surface soil bulk density was found at light military use sites. In the areas examined at Fort Benning, infantry training alone appeared to have minimal impacts on measures of soil quality aside from surface soil bulk density. Heavy use sites had the lowest stocks of labile soil C (as indicated by amounts of corrected POM-C), the highest fraction of refractory soil C, and the lowest soil C concentrations and soil C/N ratios. Thus, soil compaction can have overall adverse impact on soil quality.

Soils in each of the disturbance categories had low silt-clay contents and a high (≥ 77%) sand fraction. Sandy soils are not favorable to the physical protection of organic matter through soil aggregate formation. The extent to which the protective capacity of a soil is "filled“ (directly related to clay content) and the amount of free organic matter affect the rate at which soil C becomes physically protected.

Analysis of soil C/N ratios, as well as soil C concentrations and stocks indicated recovery of soil quality at moderate use and remediated sites relative to heavy use sites. The land use history of the moderate use sites was unknown, but they appeared to be in an early stage of successional recovery from the bare ground characteristic of heavy use sites.

Soil disturbance and changes in management practices affect the amount of POM in surface soil mineral soils, thus POM-C may be valuable long-term indicators of changes in soil quality. Although some recovery in POM-C was indicated in a comparison of remediated and heavy use sites, trends in POM-C along the chronosequence of forest stands also indicated that recovery of POM-C may be a slow process.

Considering the long-term effect of soil compaction and the potential slow accumulation of POM-C in sandy soils, heavy military use sites may be slow to recover soil quality without intervention that includes establishing actively growing vegetation. The long-term adverse effects of soil compaction might be reversed through conventional tillage and the establishment of fast growing perennial

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